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AUTHOR Marr, Beth
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ABSTRACT

This paper reports on a teaching experiment in an Australian adult numeracy class that used audio and video tapes to record the talk of students as they participated in a range of mathematical learning activities. Included were group and pair tasks designed specifically to encourage meaning-making talk to enhance students' use of mathematical language. The ongoing, grounded analysis revealed two distinct aspects of language use in the mathematics classroom. The first was the "opportunity to speak"--the space and invitation given for students to articulate and modify their thoughts about mathematical tasks through speech. The second identified aspect was the "mean to speak"--students' understanding of mathematical concepts and their ability to use the mathematical terminology intrinsic to them. Qualitative data from the study are used to differentiate between two aspects of language use and indicate advantages of attending to both within the context of adult mathematics learning. Results indicate that curriculum planning in adult mathematics classes should take into account increasing students' communicative competence. The study demonstrates that rehearsal for a larger audience, the need to express thoughts during collaborative tasks, and the need to contribute to written reflections provide students with greater opportunities to speak than traditional mathematics pedagogy. These tasks also awaken in students an interest in acquiring mathematical language. (KHR)

# How Can They Belong If They Cannot Speak the Language? Enhancing Students' Language Use in the Adult Mathematics Classroom

**Beth Marr**
**RMIT University, Australia**

A sociocultural educational perspective sees learning as induction into "discourses" or "communities of practice" through interaction with more expert others. At the heart of any discourse are the language and symbols which carry its special meanings. To become a member of the discourse one must begin to learn its language. However, in traditional mathematics classrooms, the students, those who need to learn the language, usually have the least opportunity to speak it (Pimm, 1987).

A teaching experiment with an Australian adult numeracy class used audio and video tapes to record the talk of students as they participated in a range of mathematical learning activities. Included were group and pair tasks designed specifically to encourage meaning-making talk and to enhance students' use of mathematical language. The ongoing, grounded analysis revealed two distinct aspects of language use in the mathematics classroom. The first was the "opportunity to speak": the space, and invitation, given for students to articulate and modify their thoughts about mathematical tasks, through speech. The second identified aspect was the "means to speak": students' understanding of mathematical concepts, and their ability to use the mathematical terminology intrinsic to them. This paper will use qualitative data from the study to differentiate between these two aspects of language use and indicate advantages of attending to both within the context of adult mathematics learning.

### Language From a Sociocultural Theoretical Perspective

A sociocultural, discourse oriented approach to the study of learning takes as a premise the social construction of knowledge (Bauersfeld, 1995; Lerman, 1996; Voigt, 1995; Wertsch, 1995). Fixed concepts do not exist in their own right but are invented and passed on within established conceptual frameworks within "communities of practice" or "discourses." Within these discourses are specialist language, meanings, symbols, and established forms of expression and argument of the discourse—its "register" (Pimm, 1987) and accepted ways of using that language within it—"communicative competence" (Cazden, 1986). The sociocultural perspective sees learning as induction into discourses through interaction with more expert others such as experienced players, workers, or teachers. Part of natural induction to any practice is modelling, scaffolding, and instruction of language within the practice. From this perspective, teachers of mathematics should introduce students to the language of mathematics as a natural part of their teaching.

> Having resource to language affords power to name and rename, to transform names, to use names and descriptions to conjure, communicate and control our images, our mental worlds. (Pimm, 1995, p. 1)

Conversely, what might it mean not to have the power of language? How can one reflect on things one cannot name?

Analysis of traditional school mathematics classrooms has shown that students have little opportunity to practice mathematical language. Rather, classroom discussion is usually teacher dominated. Using characteristic questioning patterns, teachers tend to elicit from students minor responses in tightly orchestrated step-by-step processes, so that those who need to learn the language get the least practice at using it (Barnes, 1976; Cazden, 1986; Edwards & Westgate, 1994; Voigt, 1995; Wood, 1994). "During frontal teaching, (teachers) elicit and control the classroom discourse step by step" (Pimm, 1987, p. 178).

Linguistic analysis by Veel (1999) revealed that tight control of this nature is more pronounced in traditional mathematics classes than in other school subjects, partly because of the dearth of explanatory written texts available to the students.

> Whereas most other subject areas rely on an extensive canon of written prose (to be found in textbooks, encyclopedias and school libraries) to provide the impression of stability and permanence to knowledge, this is noticeably absent in mathematics. Textbooks tend to be pastiches of repetitive activities and fragments of knowledge. (p. 187)

Consequently, within the traditions of mathematics teaching and learning, there is a heavy reliance on the teacher's verbal explanations to carry the knowledge and understanding of the subject. Reliance on the spoken mode begins to explain the "catechistic" type of interaction so prevalent in mathematics classrooms. A tight control must be kept on the dialogue if the teacher's knowledge is to become the students' knowledge and so power roles of teacher as "primary knower" and students as receivers of knowledge are firmly established within the traditional mathematics classroom culture (Veel, 1999).

Educators who believe that language is an important learning tool in mathematics use alternative activity structures such as group and pair investigations, with report back sessions to encourage students to find their own voice in the classroom (Adler, 1977; Cobb et al., 1995). However, detailed investigation of student utterances by Adler, Pimm, and Veel reveal: that in secondary school mathematics classes there are large gaps between students' language use and that of accepted mathematical discourse (Veel, 1999); that students seem unable to express their strategies clearly to an audience of their peers (Pimm, 1994); and that report back sessions do not reflect the richness of the small group investigations (Adler, 1997). Veel suggests that more explicit attention to mathematical discourse is necessary.

Arising from this concern are questions regarding how students can best be introduced to mathematical registers and what kind of frameworks are productive for analysing attempts to do so.

Adler (1999), describing language as a tool for learning, uses a window metaphor to illustrate two aspects of a tool: "useability" and "visibility." A window can be regarded from two different perspectives. It is usually something that people use to *look through*, a "useable" means of letting in light and views, enabling them to see. However architects and their clients, designing a building, are also concerned about the shape, size, and style of the windows. They look specifically *at the window* itself, making it "visible."

The window metaphor applied to language within mathematics learning sees students using language, first, as a means to "see," to access meaning, and to convey thinking, understanding, and strategies. For this useability of language to occur the students need to be given an opportunity to speak, to let in the light. For example, collaboration in groups or pairs, and writing or reporting to the class, might aim at encouraging talk, but not necessarily focus on language itself. However, at other times teachers might want students to look specifically at the language, to become aware of the mathematics register. They should understand its formal terms, modes of expression, and argument, such as "if...then" connections, and its forms of generalisation. They should be able to use this language themselves. This "visibility" requires teachers to specifically address the mathematical register (Pimm, 1987; Veel, 1999).

**The Research Study**

The study reported in this paper involved observation and analysis of the participants, culture, language, and communicative competence, encouraged by traditional worksheet methodology in an Australian adult mathematics classroom. A one semester teaching experiment, grounded in ongoing observations, then introduced a range of supplementary "Intervention Activities" and considered the changes in students' talk patterns and appropriation of language facilitated by the activities. The Intervention Activities incorporated group and pair structures, hands-on materials, specific language focused activities, and open-ended investigations. Using ethnographic, case-study techniques, data were collected through audio and video taping of student and teacher talk, interviews, field notes, and collection of artefacts (Bolster, 1983). The data were analysed weekly using a grounded approach, which enabled the teaching experiment to respond in an adaptive manner to the ongoing findings.

### The Program

The study took place on the main inner-suburban campus of a large multi-campus Technical and Further Education (TAFE) Institute. The class was part of a full-time certificate program: The Certificate of General Education for Adults (CGEA), a qualification framework of four levels, 1 up to 4 (ACFE, 1996) that included Mathematics in the course package. These students were roughly Level 3/4 mathematics, but varied in literacy levels. Classes ran in three-hour blocks, consequently, single sessions could include a variety of activity formats and topics.

### The Teacher

The teacher, from a progressive, primary teaching background, was one of the most popular in the program. His classes were particularly enjoyed by mathematically anxious women.

### The Student Group

The adult learners exemplified a range of ages, cultures, educational backgrounds, and motivations for studying. From a language perspective, there were two major groups. Seven were primarily in the program learning English as a second language to improve employment prospects. Originally from Italy, Libya, Lebanon, and the Philippines, they had worked in Australia prior to attending this course, some for as many as thirty years. Although the classes were conducted in English, Arabic and Italian were sometimes used between students. The twelve Australian born students had either left school early or had interrupted schooling and saw the course as a means of gaining entry to further study, some for interest or self-improvement (usually women), others because education was essential for gaining employment to support themselves and their families.

### Traditional Teaching Methodology

The usual teaching utilised calculation-based worksheets, either abstract skills practice type—derived from typical school textbook tasks; such as calculating the areas of a number of complex shapes—or "reality based" worksheets designed by the teacher around realistic applications which he assumed students would easily relate to. For example, one asked students to act as contractors to calculate fence material and grass planting costs for the local council.

In the regular classroom culture students were always given individual copies of the worksheets. Although they were encouraged to assist each other, no structuring of pair or group work was observed.

### The Intervention Activities

Activities introduced into the classroom as part of the teaching experiment were intended to serve two major purposes. The first was the exploration of mathematical concepts through hands-on materials, reflection, discussion, and sometimes writing, in group and pair situations. For example, one task asked students to use string and grid paper to investigate statements related to areas of garden that could be made with a fixed length of fencing. In another, students in small groups estimated the volumes of household containers, then collaborated to write responses to "reflective prompts" (short questions designed to encourage students to think beyond specific answers and formulate generalisations) such as "Have any of your ideas about the volume of containers changed during this activity?"

The second purpose, grounded in early observation and analysis (see below), was to encourage students to engage with the vocabulary of the topics they were studying, strengthening their use and understanding of the mathematics register. For example, one task asked students to use the mathematical language of shape to "Write Three Sentences" describing a container. Some "cloze" language activities, based on English as a Second Language (ESL) teaching models in which students are required to select the correct words to fill gaps in sentences, were also created. A more open-ended activity asked pairs of students to list the *similar* and *different* properties of the two cylinders which could be fashioned using a sheet of A4 paper.

**Framework for Analysing Classroom Talk**
An organisational framework for reporting the facets of talk remained problematic throughout the progressive analysis of the data. Adler's window metaphor finally provided the inspiration for establishing two categorisations: "the opportunity to speak" and "the means to speak."

***The opportunity to speak:*** This manner of looking at student talk refers to the space, and invitation, given for students to articulate and modify their thoughts about the tasks and engagement with the tasks, through speech. It implies an aspect of both speaking and being heard by responsive others—an "audience." It asks questions about when, and to whom, students talk as a means of exchanging meaning and feelings about the subject.

***The means to speak—mathematical language:*** This second manner of examining student talk refers to students' access to mathematical meaning and the "mathematical register" (Pimm, 1987, 1995), including their understanding of mathematical concepts and their comprehension and use of mathematical terminology related to, and intrinsic within, the mathematical concepts. It asks questions relating to the quality of the talk, terms understood, and confident use of mathematical language.

***Opportunity to Speak in the Traditional Culture***

***Lack of opportunity for students to speak in traditional whole class discussions***
Classroom discourse patterns within this adult classroom confirm many features of school classrooms described in the literature. However, a particularly jocular and light-hearted atmosphere created by the teacher counteracted students' past anxieties about mathematics classes. Individual students felt free to contribute spontaneously throughout, because he refrained from nominating particular speakers or evaluating individual responses.

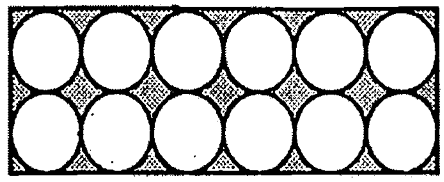
Using traditional worksheet routines of topic introduction, student practice, followed by teacher review, teacher-led segments occupied more time in total than the student practice. For example, there would be 27 minutes of teacher-led time compared to 25 minutes on student work and interaction. During these whole-class segments students customarily listened to teacher explanations and filled in answers in short manageable steps (Note: .. indicates a pause in speech; .... segments of speech omitted from transcript):

> T: *I just want to go over the way you work out some areas .. to see if you've forgotten them or not. So ..* [ draws a figure on the board as he speaks] *Area of a rectangle, and this includes squares really, .. that's seven and that's four. How do you work it out?*
> ***Ss*** ***Seven times four/twenty-eight***
> T *You multiply it together ....*

Writing and drawing on the board, he continued to detail procedures for rectangles, triangles, and circles, leaving the occasional gap for brief student responses. Students' utterances were usually one or two words only, characterised by numbers or arithmetical processes. Typical dialogues of this kind, in which teachers use controlled "discussion" to provide information, severely limit students' *opportunity to speak* in the classroom. For example, in one representative 320-word transcript, the students contributed a mere 28 words: 11 in numbers; 5 in numerical processes, such as "divide it by three"; and 5 words in a flippant interjection.

Students were sometimes invited to explain their reasoning. However, a tendency to co-opt, or rephrase, student explanations (probably to clarify them for others), meant that the intended elicitation of students' ideas was not always reflected in the quality of the outcomes. The following example illustrates the teacher mediating a student's attempted explanation by slowing down the reasoning. However, in doing so, he took over the explanation rather than encouraging student expression. (Note: ../ signifies an interrupted utterance.)

d )



10 cm diam
holes

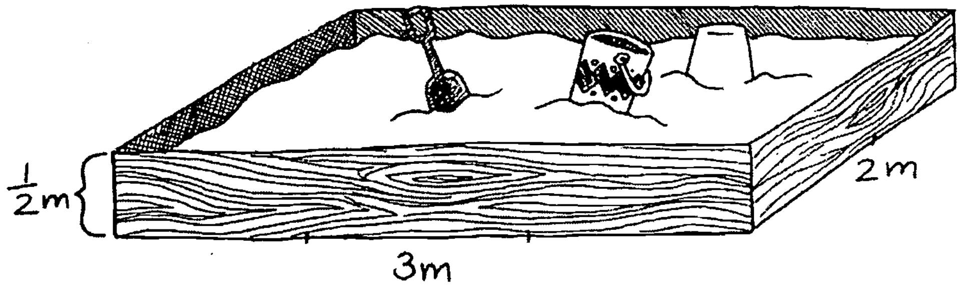
| | |
|---|---|
| *Ester* | [enthusiastic to speak] *You find the area of those holes and you subtract that ../* [interrupted by teacher] |
| *Teacher* | *So you find the area of one hole ../* |
| *Greta* | *Ten ../* |
| *Teacher* | *....which is going to be .. if ten's the diameter five is going to be the radius .. so it's five times five times three point one four ....* |

The mediation seems logical since the teacher's proximity to the board diagrams allows him to clarify students' explanations. However, the effect is that the majority of school mathematics teachers do most of the talking and mathematical naming. The interruption of students' speech limits their responses to brief numerical calculation strategies and numbers, at the expense of encouraging the use of a variety of language from the mathematical register. The students' *means to speak* is neither explored nor encouraged.

***"Cries for help" during student practice create some "opportunity to speak"***

Predictably, practice periods interrupted the asymmetry of power and control of dialogue illustrated above. They provided more opportunity for students' mathematical communication as they requested help to proceed with exercises. However both teacher-student and student-student communication during this time seemed to follow patterns of "repair work" (Bauersfeld, 1995) in which one person, the giver of knowledge, provides procedural or "how to" information to fill gaps for another less knowledgeable person, the receiver of knowledge. During these teacher-students interactions, again the teacher does most of the talking, with student responses limited to "yes" and "ah-ha" type utterances.

Similar interchanges occurred between students, although the student-student interactions were extremely procedurally focused with little discussion of why the processes were appropriate. For example, in the interchange below, Sophia clearly gave all responsibility for the process to the written rule on the board, and Mina seemed to follow her step-by-step instructions without indication of understanding. (Note the mixture of Italian and English in their private conversation.)



| | |
|---|---|
| *Mina* | *Come e fatto? .. three times two .. e poi?* <br> [What did you do .. three times two .. and then?] Translation <br> ... |
| *Sophia* | *Oh you .. the way it's explained up there you multiply the height. You go .. three metres by two metres.* |
| *Mina* | *So three times two?* |
| *Sophia* | *Yeah* |
| *Mina* | *..and doppo what about the half?* <br> [and then what about the half] Translation |
| Sophia | [inaudible] |
| *Mina* | *So you times?* <br> *Times half? .. come half? ..* [inaudible word] *a half?* <br> [how do you do the half?] Translation |
| *Sophia* | *Nought point five.* |
| *Mina* | *Point five ../* |
| *Sophia* | *For half. Then it comes out to three cubic metres.* |
| *Mina* | *Point five .. put the zero or no?* |

***Chains of assistance***
Instructions were shared generously from one student to another. For example, after the above exchange Mina relayed the procedure to another student: *"Three times two equals six times .. five .. point five .. point five."* This phenomenon of sharing information, which I have called a "chain of assistance," was common during student work. However, the instructions usually became more procedural and stripped of explanatory information as they passed along the chain.

Although students received greater *opportunity to speak* during worksheet practice periods, their *means to speak*, the appropriation of the mathematical register, and understanding of concepts, was not necessarily increasing.

***Opportunity to speak using the intervention activities***
Structured group and pair tasks, centred around concrete materials, proved to be one means of changing traditional communication patterns. Since students were not expected to undertake calculations alone, there seemed less necessity for long teacher introductory dialogues, so the *opportunity to speak* became more immediate. The nature of student-student interactions shifted from givers and receivers of information to a more exploratory form of collaboration (Mercer, 1995). Rather than one student waiting until another had worked out an answer then requesting help, which came as fully thought out opinions or procedures, students explored more conceptual ideas together in a collaborative manner. (This was a process not only facilitated by the cooperative structures and concrete materials, but by the different nature of questions they allowed.) For example, students manipulating string on grid paper explored area shape and perimeter together:

| | |
|---|---|
| *Elaine* | *What she's saying is she owns a rectangular garden and she wants to make another rectangular garden with the same amount of fencing and a larger area.* <br> [Interpreting the question] |
| *Greta* | *Yeah. Yeah.* |
| *Elaine* | *It can be done.* |
| *Sarah* | *Can it?....* [briefly inaudible] |
| *Robyn* | *Instead of making the garden long and thin. That's what you are saying aren't you? But it's still a rectangle.* |
| *Elaine* | *Yeah.* |
| *Sarah* | *OK. Is that what you mean when .. you make it with the same amount of string?* |

As well as becoming more collaborative in nature, the character of student-student interactions became less procedural. In many cases their conceptual knowledge and intrinsic terminology was clarified because understanding language, such as "rectangular" or "cube" was embedded in the tasks. For example, when exploring cubes made with small MAB blocks, Jackson suddenly realised how to determine the number of cubic centimetres in a cube and its connection with $x^2$and $x^3$ formulations. ***"That's it! That's it!*** *Don't go any further! The number has to be timesed three times to make a cube."* He then shared his discovery in an excited voice:

> *.. Cube the number mate. Equals four time four times four. .. That's, that's why we have square root - you know how we have "square" and "cubed." That's what cube stands for.*

Responses to the true or false statement "Stephan carried a cubic metre of soil in his wheelbarrow," typified similar exchanges about meaning:

| | |
|---|---|
| *Mina* | *Quanti a cubic metre?* |
| | [How big is a cubic metre?] Translation |
| *Bruna* | *The larghetsa .. the altetsa .. egualli..* |
| | [The length and the height are equal] Translation |
| | Her explanation was then taken up in English: |
| *Sophia* | *Imagine a .. imagine a whole container... the same length and the same width and the same - a cubic metre* |

***"Rehearsing" student explanations to increase student voice***

An explicit strategy for encouraging longer student explanation involved asking pairs of students to rehearse their reasoning for brief questions such as "Which is bigger 1600 cc or 1 1/2 litres?" This strategy significantly increased the length of student utterances to the whole class. For example:

> *.... we thought together that ... you convert the one cubic centimetre to millilitres .. millilitres you get um .. then it's equal the one and a half litres .. and so therefore the one thousand six hundred is greater than one thousand five hundred. So the one thousand six hundred ccs is the greater. I went around the world to say that ....*

Claire's final comment implies that the speech seemed very long to her. It indicates the expectations of student speech within the prevailing culture, where students were seldom encouraged to explain their thinking. However, in comparison to the teacher's usual contributions, Claire's was quite short.

During these invited student explanations other students paid close attention and acknowledged their understanding. *"See that's what she did. She converted it to liquid, and it makes it simple."*

***Divergent tasks change teacher-student interactions***

Students' divergent approaches to group investigation problems allowed a change in the quality of teacher-student interactions. Differing responses gave the teacher a real purpose to act as "audience" listening to students, rather than always answering their cries for help as before. For example, *"we counted up the squares, right? and then we get the area ...and then we did a triangular shaped fence."* Or when Jackson related to the teacher his strategies for finding all possible dimensions of box shapes with a volume of twenty four: *"Well I did it in equation form right? I thought of all the different equations that times to get twenty four. So have a look at this."*

***Means to Speak During the Intervention Activities***

Although the initial activities trialed provided more *opportunity to speak,* there were early indications that students' *means to speak* was problematic. Students did not use the mathematical register naturally; rather, they tended to rely on "spontaneous," or everyday, language (Boomer, 1986) which made it difficult to express their conceptualisations adequately. For instance, early in the teaching experiment students were asked to write group reflections after the volume/shape estimation task. It became clear that they did not naturally use the term "volume" but tried to describe the concept with *"carry the same amounts"* or the imprecise *"bigger."* It was these results that prompted the creation of tasks specifically designed to focus on mathematical language, an important aspect of the *means to speak*.

The introductory brainstorm for the first language task demonstrated that even English speaking students lacked confidence with the language of shape: *"Spherical? Is that a word?"*; *"Is a pyramid a triangle?"* However, their questions also indicated the students' willingness to "attend" to language and experiment with it. For instance, when Jackson experimented with the "-ical" ending the teacher had modelled for conical, and cylindrical: "*... Hexogonical .. hexoconical .. Hexagon? .. so it must be hexagonical .. I've never heard of such a word .. Can I borrow your dictionary?*" Similarly Mina's appropriation of the modelled language was apparent as she rehearsed her written response: *"the volume .. the cylindrical shape .. has more volume."*

Tasks which asked students to write and discuss conceptual ideas gave them permission to take the language of the subject seriously. In her interview Sarah, a keen mathematics student, commented on the effort involved in putting her mathematical thinking into words:

> *.... like myself, I fall over my words a lot .. not fall over my words .. but you know what you are saying but you can't explain.. You have to I don't know, be really articulate .. to come sort of out with .. or you know, really verbal .... but I suppose you get taught that.*

When she did manage to articulate her thoughts she was obviously pleased with her efforts *"It is a cylindrical shaped bottle with a round base - mm quite eloquent."* So although she found it difficult to express herself in mathematics, she seemed pleased that she was improving in this aspect and had become conscious of it as a part of the subject.

Benefits from specific language tasks appeared to flow into later activities as students' conversations became qualitatively different, using language appropriated from earlier tasks in later discussions. For example, when considering "How many litres are there in a cubic metre?" and "What would it weigh if it was filled with water?" a group measured the litre (large MAB block) along the edges of the constructed cubic metre. *"But how many of those go across?"*; *"It'll be ten"*; *"Well is that ten by ten by ten, to get the three dimensions? .. So a thousand litres."* "Dimension" was a word that had not been available to students several weeks earlier, but had been introduced to help them explain the difference between a circle and a cylinder.

When listing similar and different properties of A4 cylinders, students used many terms that had been rehearsed and clarified in the prior cloze exercise. For example, English learners Isabel and Bruna, usually diffident regarding language, contributed: *"It holds more .. it is different in volume," "circular base," "cylindrical,"* and *"capacity"* to the class discussion. This type of contribution, involving the naming of mathematical properties, contrasts with student utterances during the calculation-based worksheets, in which numerical answers would have been the only verbal responses. More specific studies would be necessary to see whether communication changes of this nature would be lasting, however the results from these few instances were sufficiently encouraging to indicate that further work in this area is worthwhile.

The results of this experiment indicate that curriculum planning in adult mathematics and numeracy classes should take account of increasing students' communicative competence. The study demonstrates that rehearsal for a larger audience, the need to express thoughts during collaborative tasks, and finally the need to contribute to written reflections all provide students with greater *opportunity to speak* than traditional mathematics pedagogy. These tasks also awaken in students an interest in acquiring language with which to express themselves, the *means to speak*. The results show that this aspect of language will benefit from supplementing the conceptual tasks with activities that focus on written and oral use of mathematical terminology.

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